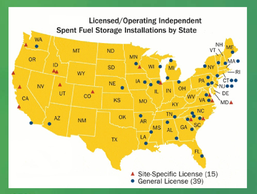
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Office of Nuclear Regulatory Research

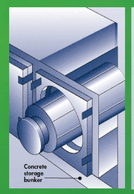
NRC Research on Environmentally Assisted Cracking of Dry Storage Canisters

Introduction

- Commercial nuclear power plants refuel every 18 to 24 months.
- Spent nuclear fuel is removed from the reactor and placed in spent fuel pools for a minimum of 5 years.
- Independent Spent Fuel Storage Installations (ISFSIs), licensed under Title 10 of the Code of Federal Regulations Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," are used when spent fuel pools have reached capacity.



ISFSI locations



Dry storage system designs

Dry Storage Systems

- Typically, canisters are constructed using 304/304L/ 316/316L stainless steel (SS).
- SS canisters are housed within a concrete bunker or a steel and concrete outer cask with passive ventilation.
- ISFSIs are licensed for 20 years.
- 3 ISFSI site License renewals (40 years) are completed.

Issues

- Exposure to coastal atmospheres may result in deposition and accumulation of chloride-containing salts which may induce chloride stress corrosion cracking (SCC).
- The Office of Nuclear Regulatory Research is evaluating the extended operation of existing ISFSIs and the potential for canister degradation.

Objective

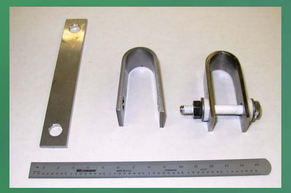
- Conduct accelerated laboratory tests to determine the SCC susceptibility of austenitic type 304, 304L, and 316L stainless steels in coastal atmospheres.



Dry storage system examples

Coastal Atmospheres

- Chloride deposition rates are dependent on distance from the coast, prevailing winds, and elevation.
- Deposition rates vary seasonally and annually.
- High and low relative humidity periods can occur daily.
- Chloride deposition rates may beas high as 200 mg/m^2/day at a distance of 1 km from the coast.

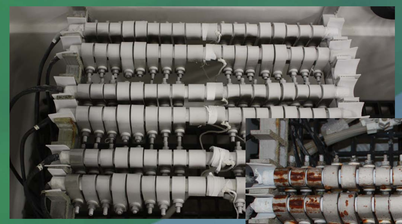

U-bend specimens

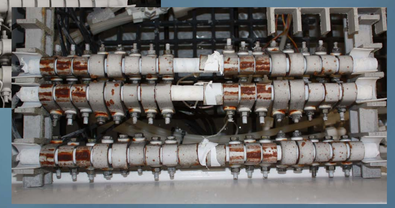
Specimen Configurations

- Single U-bend: 304, 304L, 316L.
- Double U-bend: 304, 316L.
- Gas tungsten arc welded U-bends: 304/308, 304L/308L, 316L/316L.
- Specimens conform to ASTM standards.

Accelerated Atmospheric Testing

- Specimens placed in atmospheric test chamber and heated to 40, 85, and 120 ^{o}C (104, 185, and 248 ^{o}F).
- Dry salt deposited on specimens over a 2-week period to simulate up to 18 months of exposure in a coastal atmosphere.
- High and low humidity intervals are alternated to simulate daily fluctuations.
- Test specimens are examined after 4-, 16-, and 32-week exposures.

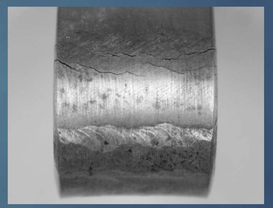

U-bend specimens after dry salt deposition for 2 weeks

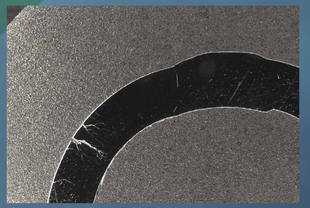

U-bend specimens tested at 40^{o}C (104^{o}F) for 4 weeks showing visible indications of corrosion

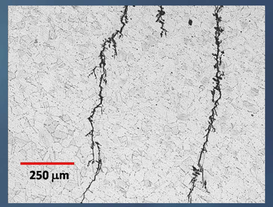
Test Results

- No corrosion or SCC ocured after dry salt deposition.
- SCC occurred on specimens tested at 40 ^{o}C (104 ^{o}F).
  - High relative humidity led to the formation of chloride-containing solutions.
- SCC of 316L was slightly delayed compared to 304 and 304L.
- No SCC occurred on specimens tested at 85 and 120 ^{o}C (185 and 248 ^{o}F).
  - Lower relative humidity at the higher temperatures precluded the formation of chloride-containing solutions.


Type 304 U-bend specimen after testing for 16 weeks at 40 ^{o}C (104 ^{o}F)


Type 30L/308L U-bend specimen after testing for 32 weeks at 40 ^{o}C (104 ^{o}F)


Cross-section of Type 304L/308L U-bend specimen after testing for 32 weeks at 40 ^{o}C (104 ^{o}F)



Intergranular cracks in a Type 304 U-bend specimen after testing for 16 weeks at 40 ^{o}C (104 ^{o}F)

Conclusions

- The formation of chloride-containing solutions at high relative humidity values can promote SCC in austenitic stainless steels.
- Higher temperatures and lower relative humidity prevent the formation of chloride-containing solutions that can promote SCC.
- SCC of ISFSI storage casks appears to be limited to a narrow range of conditions and is more likely with increased operational time as the storage canister surface temperatures decrease.

Knowledge for Today and Tomorrow